FIG. 1 (A)

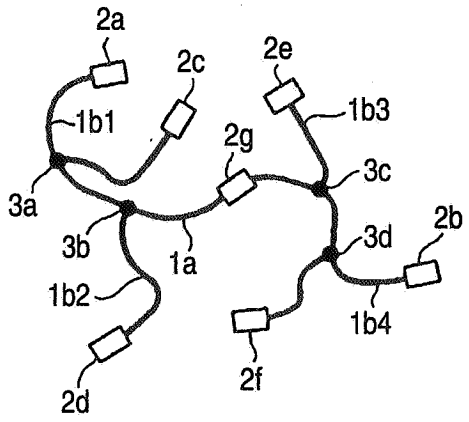

2a
2c
2e
1b1
1b3
2g
3a
3c
2b
3b
1a
3d
1b2
1b4
2f
2d

FIG. 1 (B)

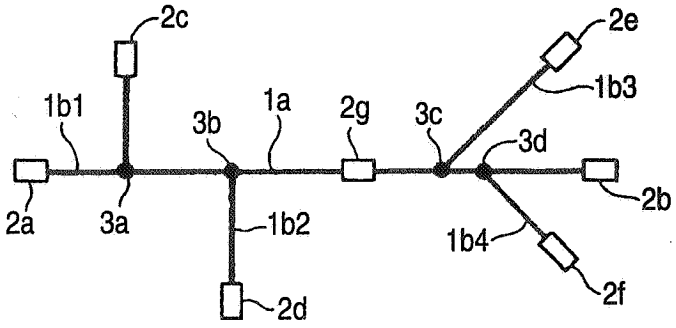

2c
2e
1b1
1b3
3b
1a
2g
3c
3d
2a
3a
1b2
2b
1b4
2f
2d

FIG. 2 (A)

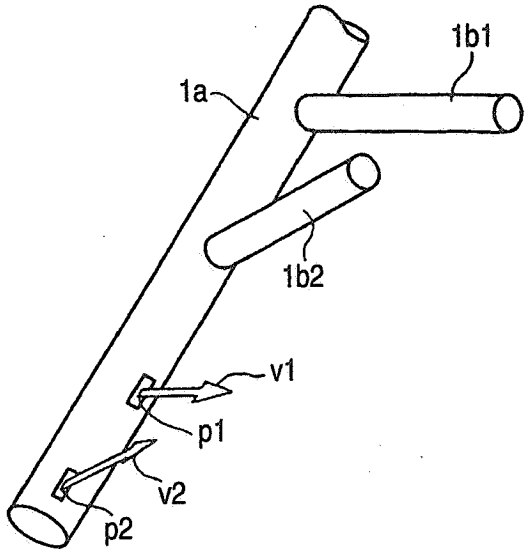


FIG. 2 (B)

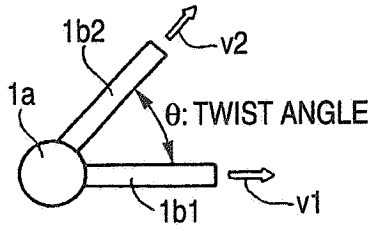


FIG. 3

	RESTRAINED DEGREES OF FREEDOM / SUPPORT MEMBER	X-AXIS TRANSLATION	Y-AXIS TRANSLATION	Z-AXIS TRANSLATION	X-AXIS ROTATION	Y-AXIS ROTATION	Z-AXIS ROTATION
COMPLETE RESTRAINT	CONNECTOR	DISABLED	DISABLED	DISABLED	DISABLED	DISABLED	DISABLED
COMPLETE RESTRAINT	LONG-HOLE CLAMP	DISABLED	DISABLED	DISABLED	DISABLED	DISABLED	DISABLED
ROTATIONAL RESTRAINT	ROUND-HOLE CLAMP	DISABLED	DISABLED	DISABLED	DISABLED	DISABLED	ENABLED
ROTATIONAL RESTRAINT	CORRUGATED LONG-HOLE CLAMP	DISABLED	DISABLED	DISABLED	ENABLED	DISABLED	DISABLED
ROTATIONAL RESTRAINT	CORRUGATED ROUND-HOLE CLAMP	DISABLED	DISABLED	DISABLED	ENABLED	DISABLED	ENABLED
COMPLETE FREEDOM	BRANCH POINT	ENABLED	ENABLED	ENABLED	ENABLED	ENABLED	ENABLED

FIG. 4 (A)

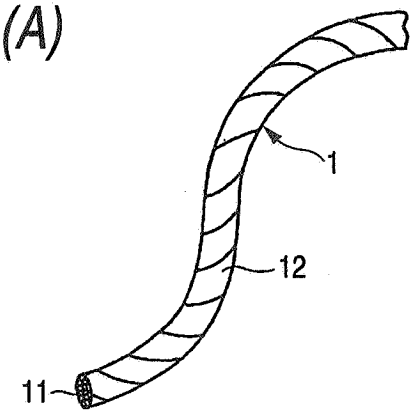


FIG. 4 (B)

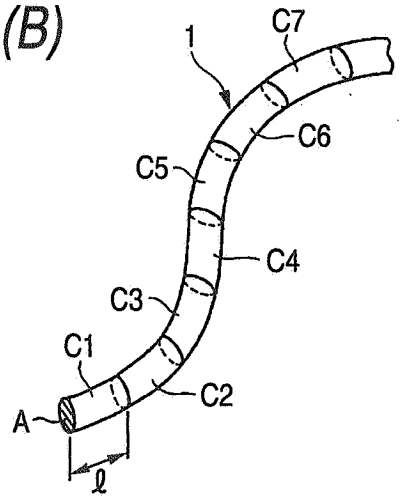


FIG. 4 (C)

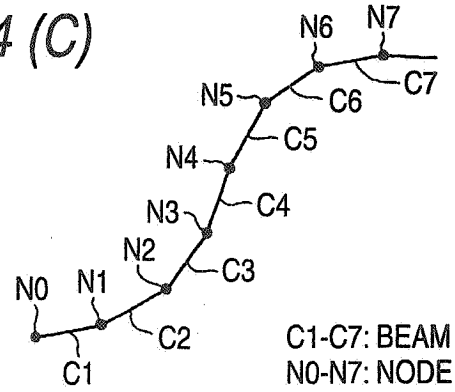
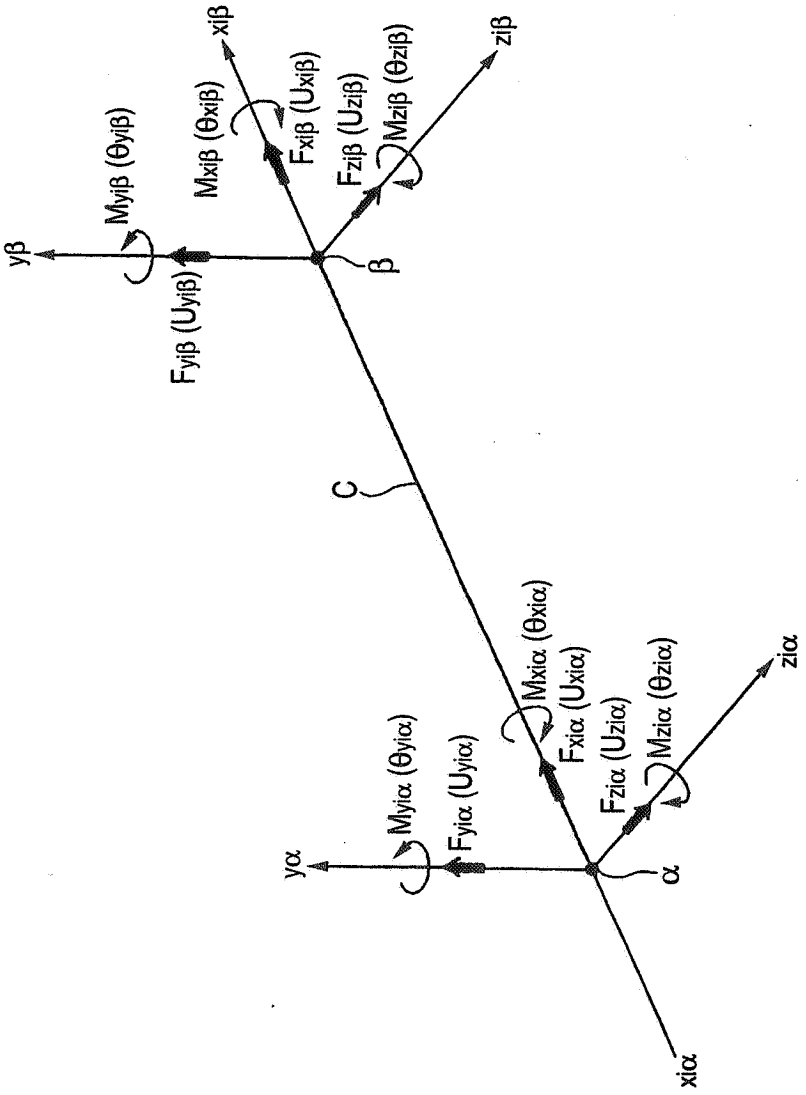
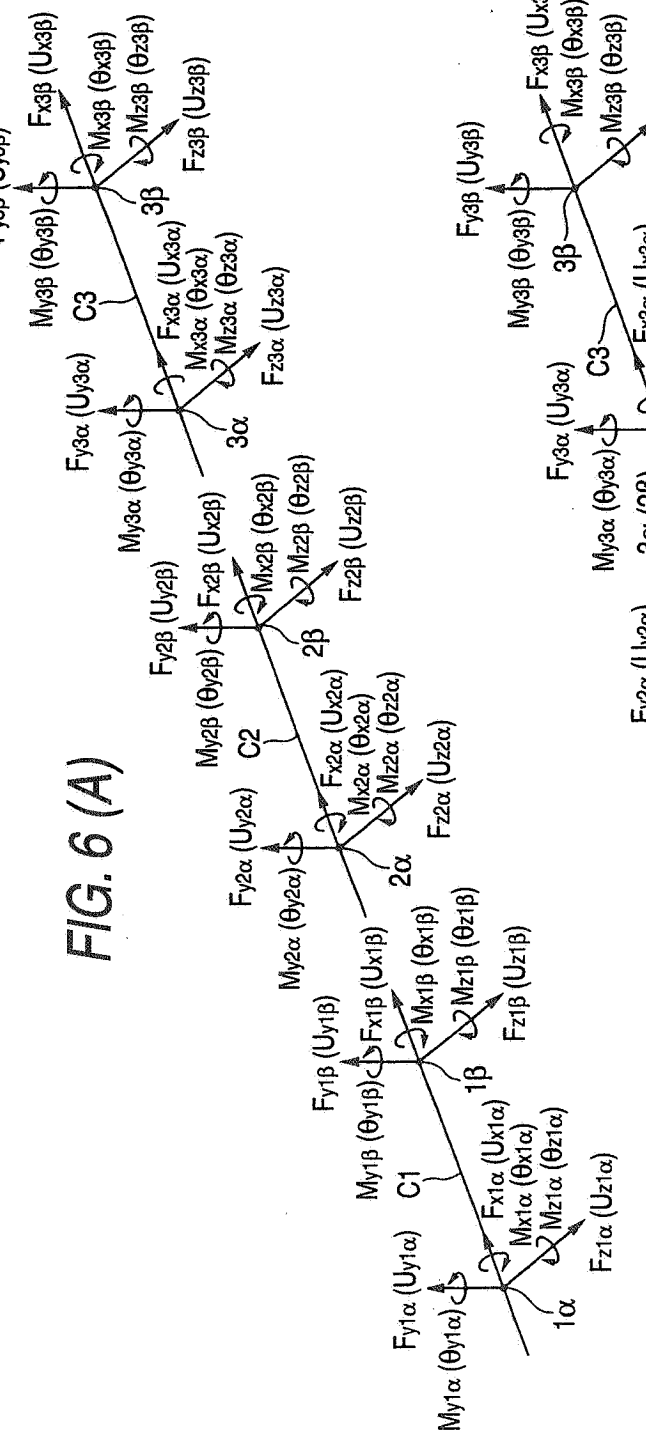


FIG. 5


xiβ
ziβ
Mxiβ (θxiβ)
Fxiβ (Uxiβ)
Fziβ (Uziβ)
Mziβ (θziβ)
yβ
Myiβ (θyiβ)
Fyiβ (Uyiβ)
β
C
Mxiα (θxiα)
Fxiα (Uxiα)
Fziα (Uziα)
Mziα (θziα)
ziα
yα
Myiα (θyiα)
Fyiα (Uyiα)
α
xiα


Fy3β (Uy3β)
Fx3β (Ux3β)
My3β (θy3β)
Mx3β (θx3β)
Mz3β (θz3β)
Fz3β (Uz3β)
3β
C3
Fy3α (Uy3α)
Fx3α (Ux3α)
My3α (θy3α)
Mx3α (θx3α)
Mz3α (θz3α)
Fz3α (Uz3α)
3α
Fy2β (Uy2β)
Fx2β (Ux2β)
My2β (θy2β)
Mx2β (θx2β)
Mz2β (θz2β)
Fz2β (Uz2β)
2β
C2
Fy2α (Uy2α)
Fx2α (Ux2α)
My2α (θy2α)
Mx2α (θx2α)
Mz2α (θz2α)
Fz2α (Uz2α)
2α
Fy1β (Uy1β)
Fx1β (Ux1β)
My1β (θy1β)
Mx1β (θx1β)
Mz1β (θz1β)
Fz1β (Uz1β)
1β
C1
Fy1α (Uy1α)
Fx1α (Ux1α)
My1α (θy1α)
Mx1α (θx1α)
Mz1α (θz1α)
Fz1α (Uz1α)
1α
FIG. 6 (A)
Fy3β (Uy3β)
Fx3β (Ux3β)
My3β (θy3β)
Mx3β (θx3β)
Mz3β (θz3β)
Fz3β (Uz3β)
3β
C3
Fy3α (Uy3α)
Fx3α (Ux3α)
My3α (θy3α)
Mx3α (θx3α)
Mz3α (θz3α)
Fz3α (Uz3α)
3α (2β)
C2
Fy2α (Uy2α)
Fx2α (Ux2α)
My2α (θy2α)
Mx2α (θx2α)
Mz2α (θz2α)
Fz2α (Uz2α)
2α (1β)
C1
Fy1α (Uy1α)
Fx1α (Ux1α)
My1α (θy1α)
Mx1α (θx1α)
Mz1α (θz1α)
Fz1α (Uz1α)
1α
FIG. 6 (B)

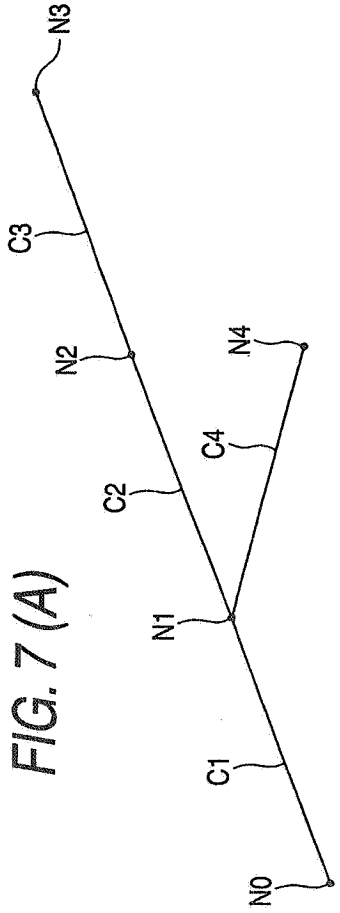

N3
C3
N2
C2
N4
C4
N1
C1
N0

FIG. 7 (A)

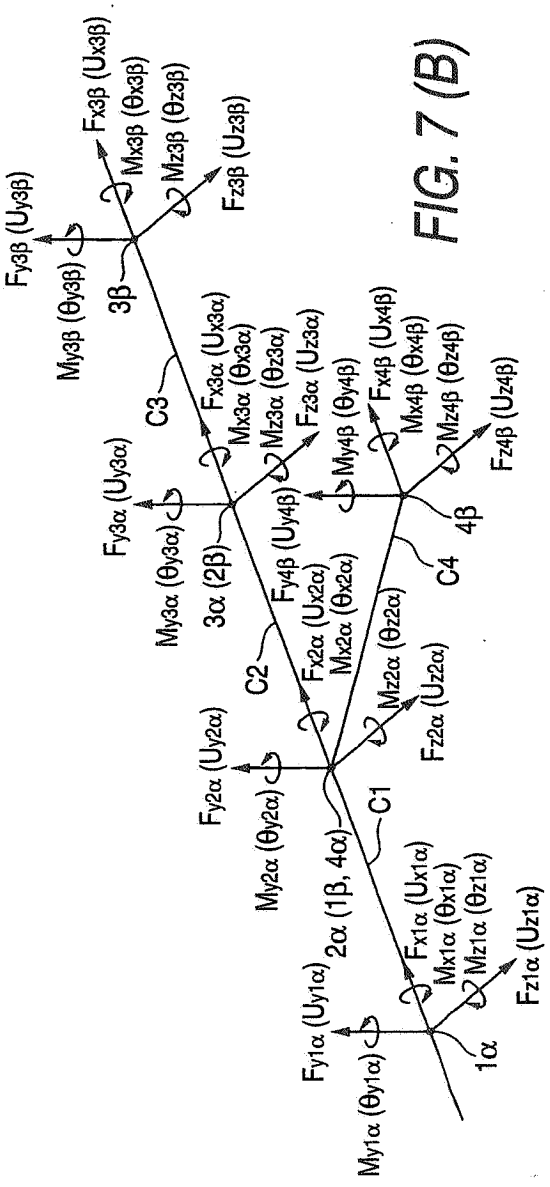

Fx3β (Ux3β)
Mx3β (θx3β)
Mz3β (θz3β)
Fz3β (Uz3β)
Fy3β (Uy3β)
My3β (θy3β)
3β
C3
Fx3α (Ux3α)
Mx3α (θx3α)
Mz3α (θz3α)
Fz3α (Uz3α)
Fy3α (Uy3α)
My3α (θy3α)
3α (2β)
C2
Fx4β (Ux4β)
Mx4β (θx4β)
Mz4β (θz4β)
Fz4β (Uz4β)
My4β (θy4β)
Fy4β (Uy4β)
C4
4β
Fx2α (Ux2α)
Mx2α (θx2α)
Mz2α (θz2α)
Fz2α (Uz2α)
Fy2α (Uy2α)
My2α (θy2α)
2α (1β, 4α)
C1
Fx1α (Ux1α)
Mx1α (θx1α)
Mz1α (θz1α)
Fz1α (Uz1α)
Fy1α (Uy1α)
My1α (θy1α)
1α

FIG. 7 (B)

FIG. 8 (A)

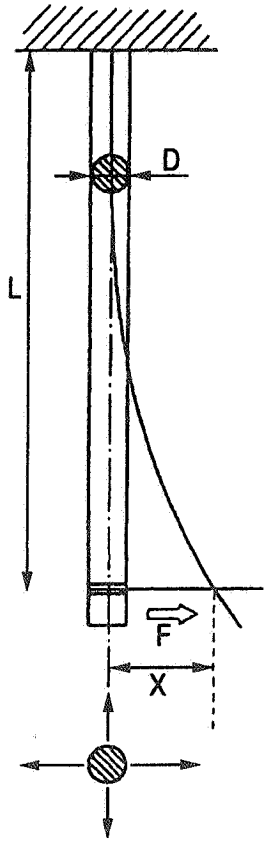


FIG. 8 (B)

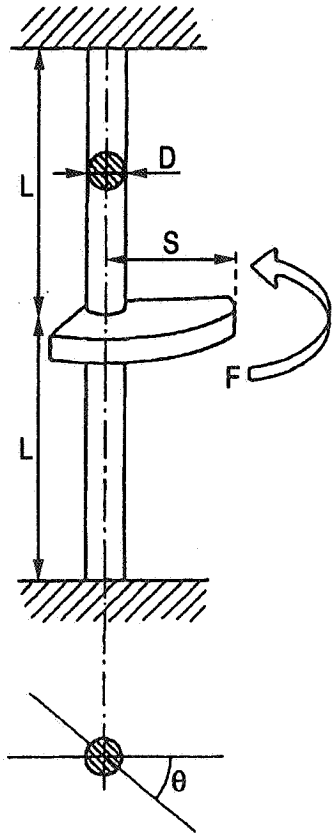


FIG. 9

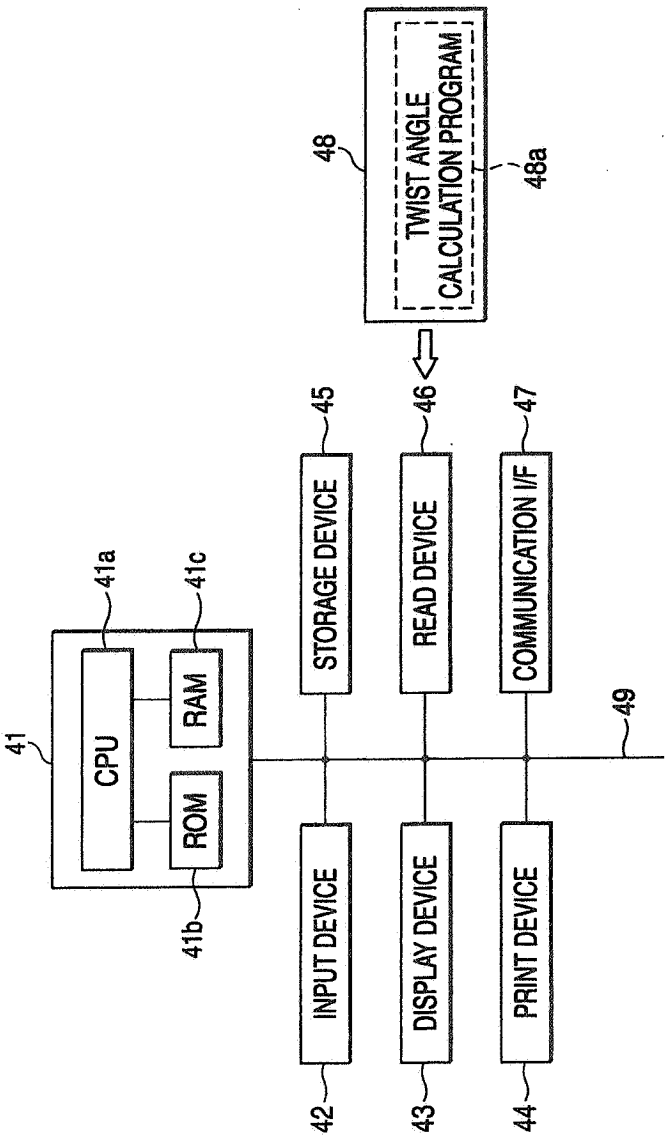

48
TWIST ANGLE CALCULATION PROGRAM
48a
45
46
47
STORAGE DEVICE
READ DEVICE
COMMUNICATION I/F
41
41a
41c
CPU
RAM
ROM
41b
49
INPUT DEVICE
DISPLAY DEVICE
PRINT DEVICE
42
43
44

FIG. 10

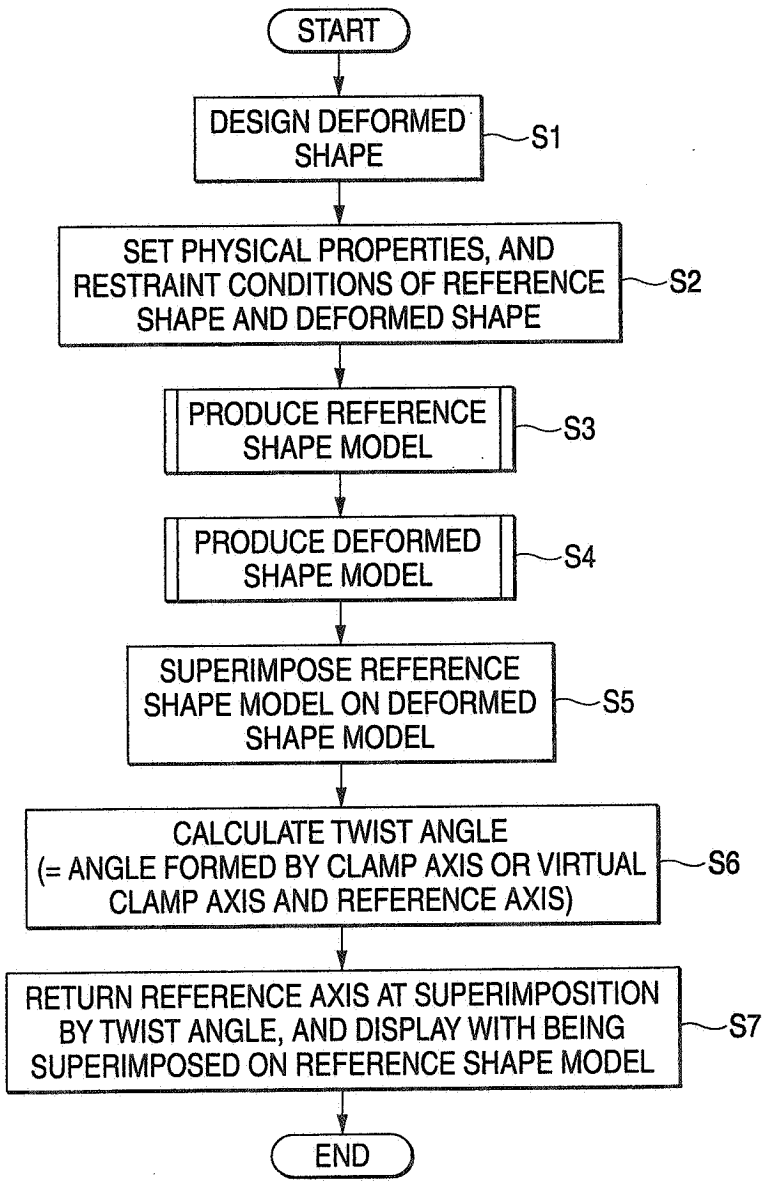

START
DESIGN DEFORMED SHAPE
S1
SET PHYSICAL PROPERTIES, AND RESTRAINT CONDITIONS OF REFERENCE SHAPE AND DEFORMED SHAPE
S2
PRODUCE REFERENCE SHAPE MODEL
S3
PRODUCE DEFORMED SHAPE MODEL
S4
SUPERIMPOSE REFERENCE SHAPE MODEL ON DEFORMED SHAPE MODEL
S5
CALCULATE TWIST ANGLE (= ANGLE FORMED BY CLAMP AXIS OR VIRTUAL CLAMP AXIS AND REFERENCE AXIS)
S6
RETURN REFERENCE AXIS AT SUPERIMPOSITION BY TWIST ANGLE, AND DISPLAY WITH BEING SUPERIMPOSED ON REFERENCE SHAPE MODEL
S7
END

FIG. 11 (A)

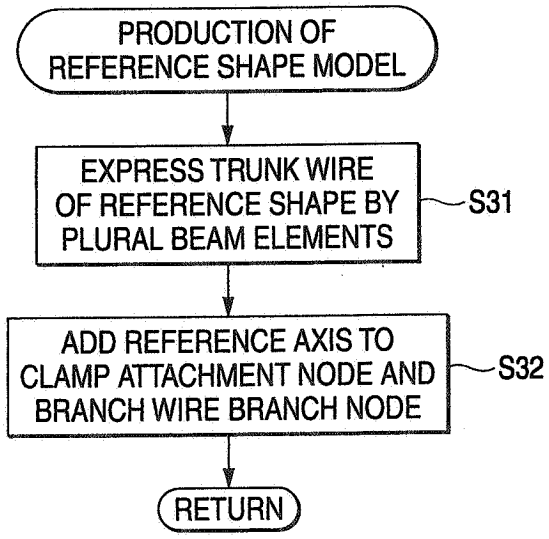

PRODUCTION OF REFERENCE SHAPE MODEL
EXPRESS TRUNK WIRE OF REFERENCE SHAPE BY PLURAL BEAM ELEMENTS
S31
ADD REFERENCE AXIS TO CLAMP ATTACHMENT NODE AND BRANCH WIRE BRANCH NODE
S32
RETURN

FIG. 11 (B)

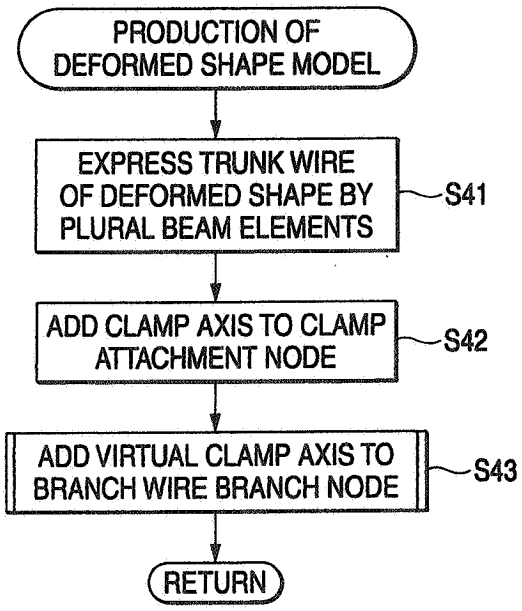

PRODUCTION OF DEFORMED SHAPE MODEL
EXPRESS TRUNK WIRE OF DEFORMED SHAPE BY PLURAL BEAM ELEMENTS
S41
ADD CLAMP AXIS TO CLAMP ATTACHMENT NODE
S42
ADD VIRTUAL CLAMP AXIS TO BRANCH WIRE BRANCH NODE
S43
RETURN

FIG. 11 (C)

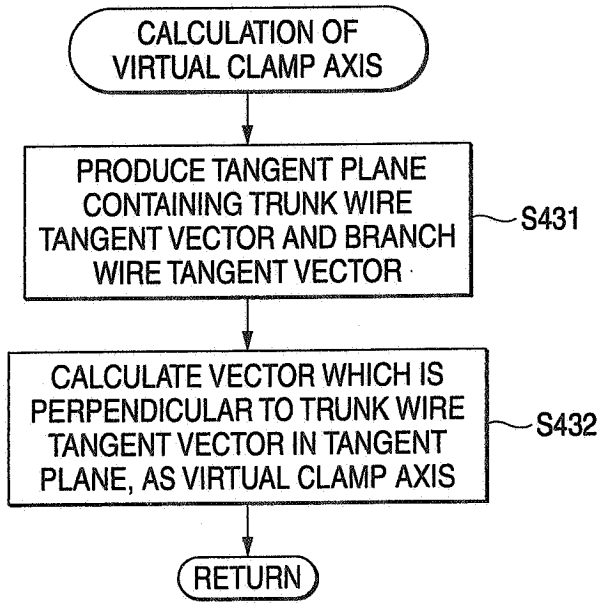

CALCULATION OF VIRTUAL CLAMP AXIS
PRODUCE TANGENT PLANE CONTAINING TRUNK WIRE TANGENT VECTOR AND BRANCH WIRE TANGENT VECTOR
S431
CALCULATE VECTOR WHICH IS PERPENDICULAR TO TRUNK WIRE TANGENT VECTOR IN TANGENT PLANE, AS VIRTUAL CLAMP AXIS
S432
RETURN

FIG. 12 (A)

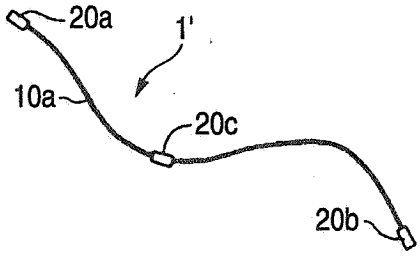


FIG. 12 (B)

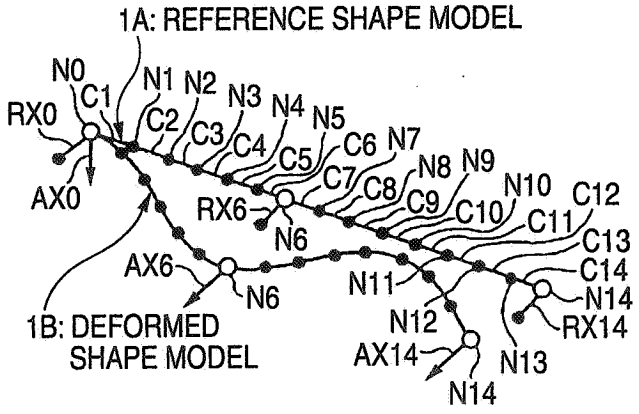


FIG. 12 (C)

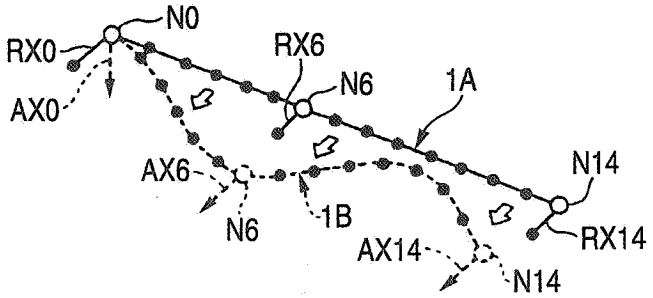


FIG. 12 (D)

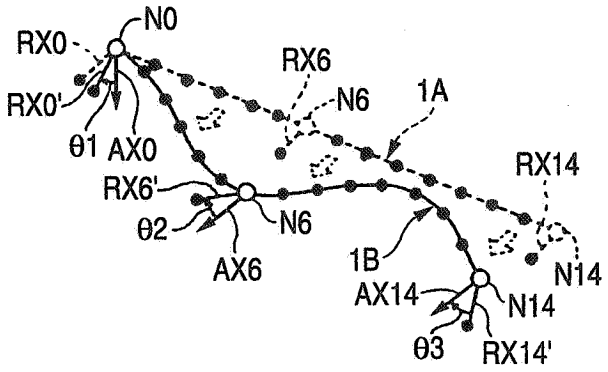
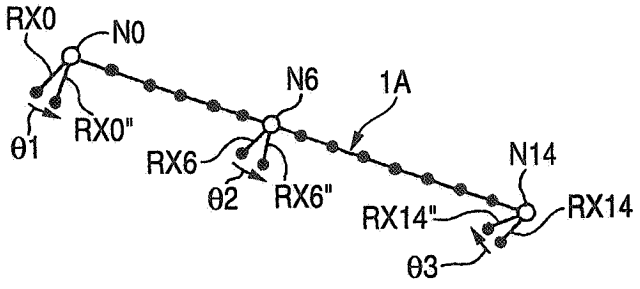


FIG. 12 (E)



θ1-θ3: TWIST ANGLE

FIG. 13

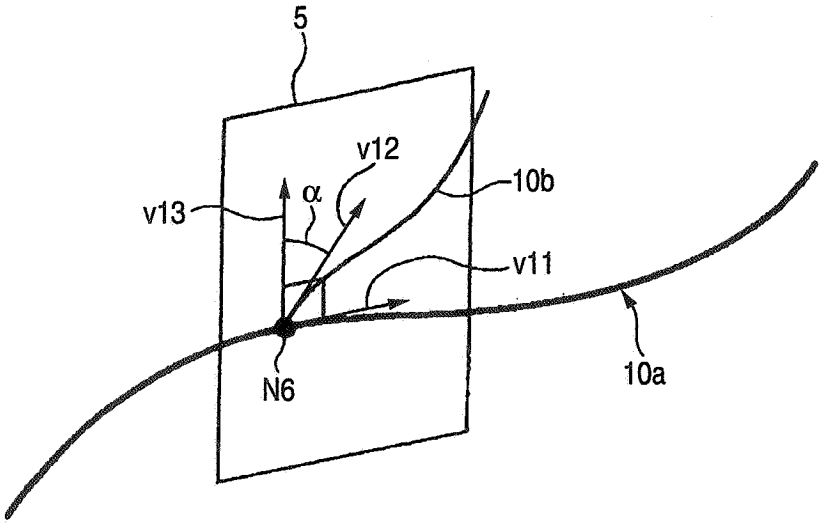


FIG. 14

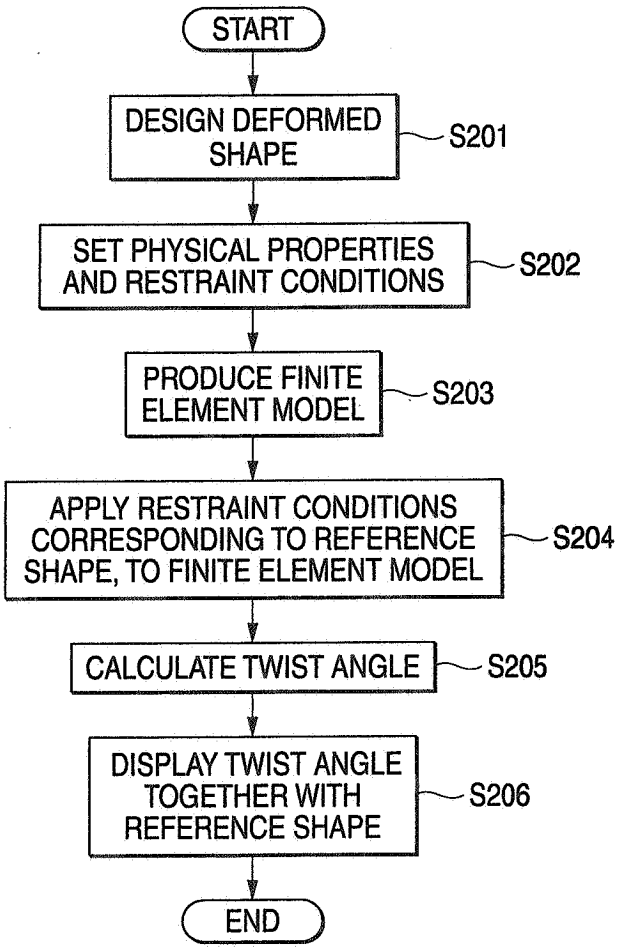

START
DESIGN DEFORMED SHAPE
S201
SET PHYSICAL PROPERTIES AND RESTRAINT CONDITIONS
S202
PRODUCE FINITE ELEMENT MODEL
S203
APPLY RESTRAINT CONDITIONS CORRESPONDING TO REFERENCE SHAPE, TO FINITE ELEMENT MODEL
S204
CALCULATE TWIST ANGLE
S205
DISPLAY TWIST ANGLE TOGETHER WITH REFERENCE SHAPE
S206
END

FIG. 15 (A)

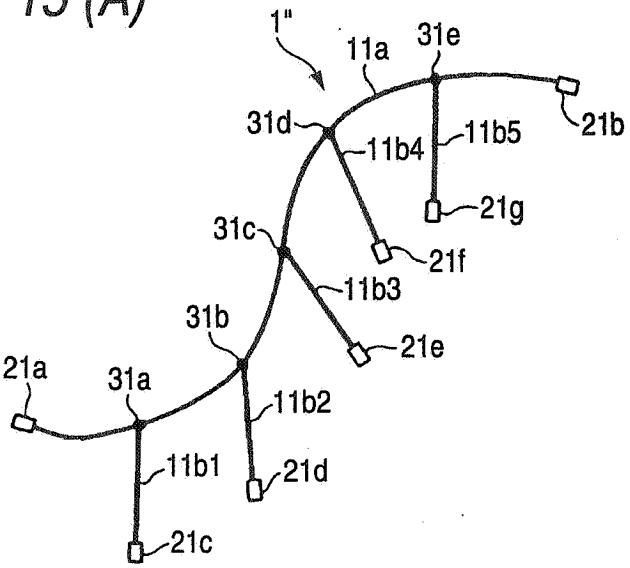


FIG. 15 (B)

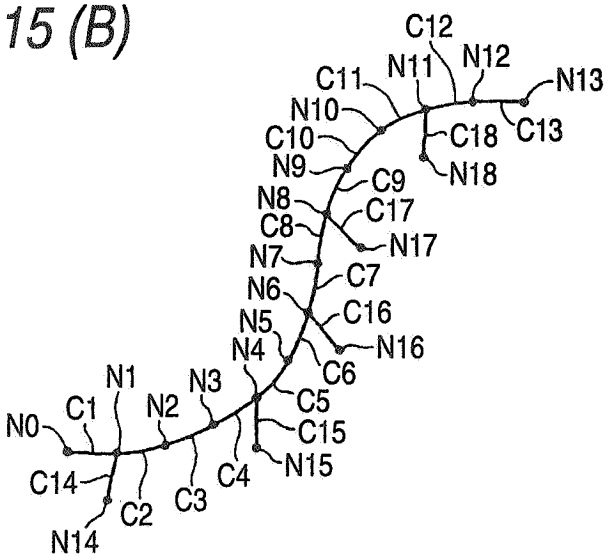


FIG. 15 (C)

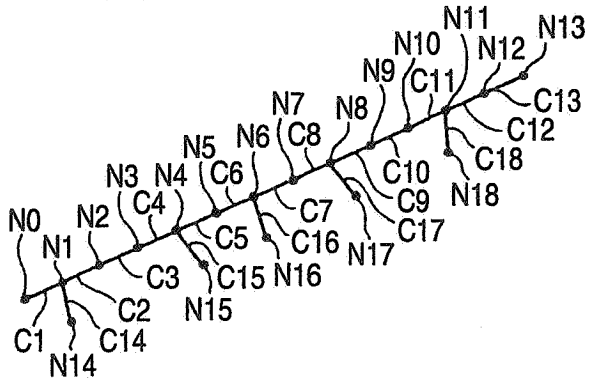
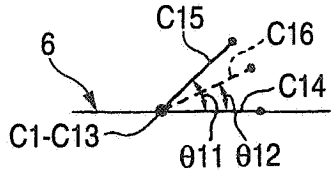


FIG. 15 (D)



θ11, θ12: TWIST ANGLE

FIG. 16

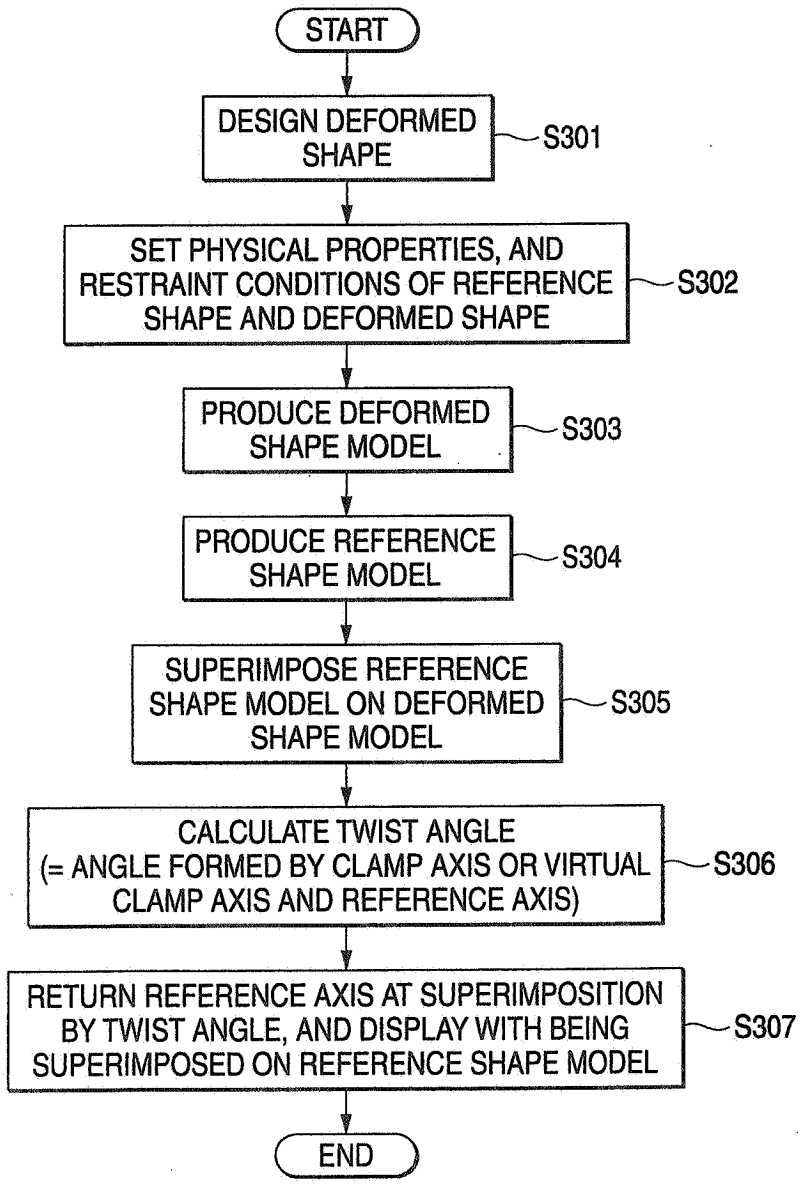

START
DESIGN DEFORMED SHAPE
S301
SET PHYSICAL PROPERTIES, AND RESTRAINT CONDITIONS OF REFERENCE SHAPE AND DEFORMED SHAPE
S302
PRODUCE DEFORMED SHAPE MODEL
S303
PRODUCE REFERENCE SHAPE MODEL
S304
SUPERIMPOSE REFERENCE SHAPE MODEL ON DEFORMED SHAPE MODEL
S305
CALCULATE TWIST ANGLE (= ANGLE FORMED BY CLAMP AXIS OR VIRTUAL CLAMP AXIS AND REFERENCE AXIS)
S306
RETURN REFERENCE AXIS AT SUPERIMPOSITION BY TWIST ANGLE, AND DISPLAY WITH BEING SUPERIMPOSED ON REFERENCE SHAPE MODEL
S307
END

FIG. 17

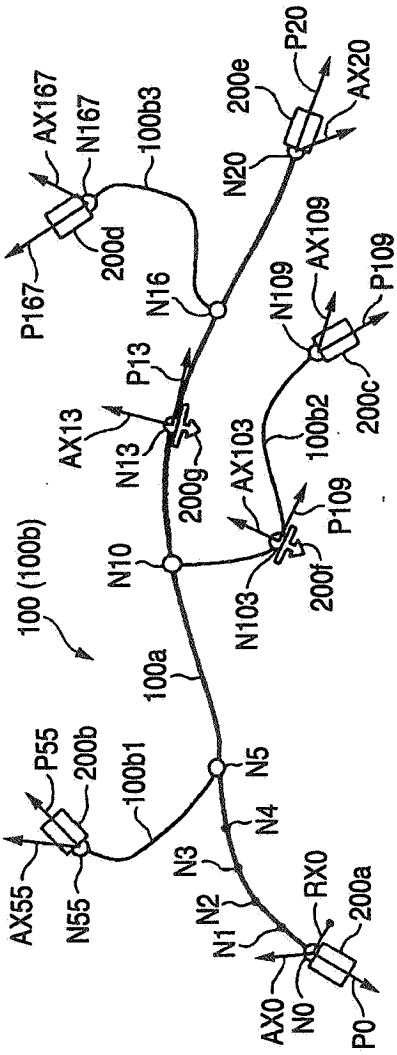

AX167
N167
100b3
200e
P20
AX20
N20
200d
P167
N16
N109
AX109
P109
P13
AX13
N13
200g
AX103
100b2
200c
P109
N10
200f
N103
100 (100b)
100a
P55
200b
100b1
N5
N4
N3
AX55
N55
N2
N1
RX0
200a
AX0
N0
P0

FIG. 18

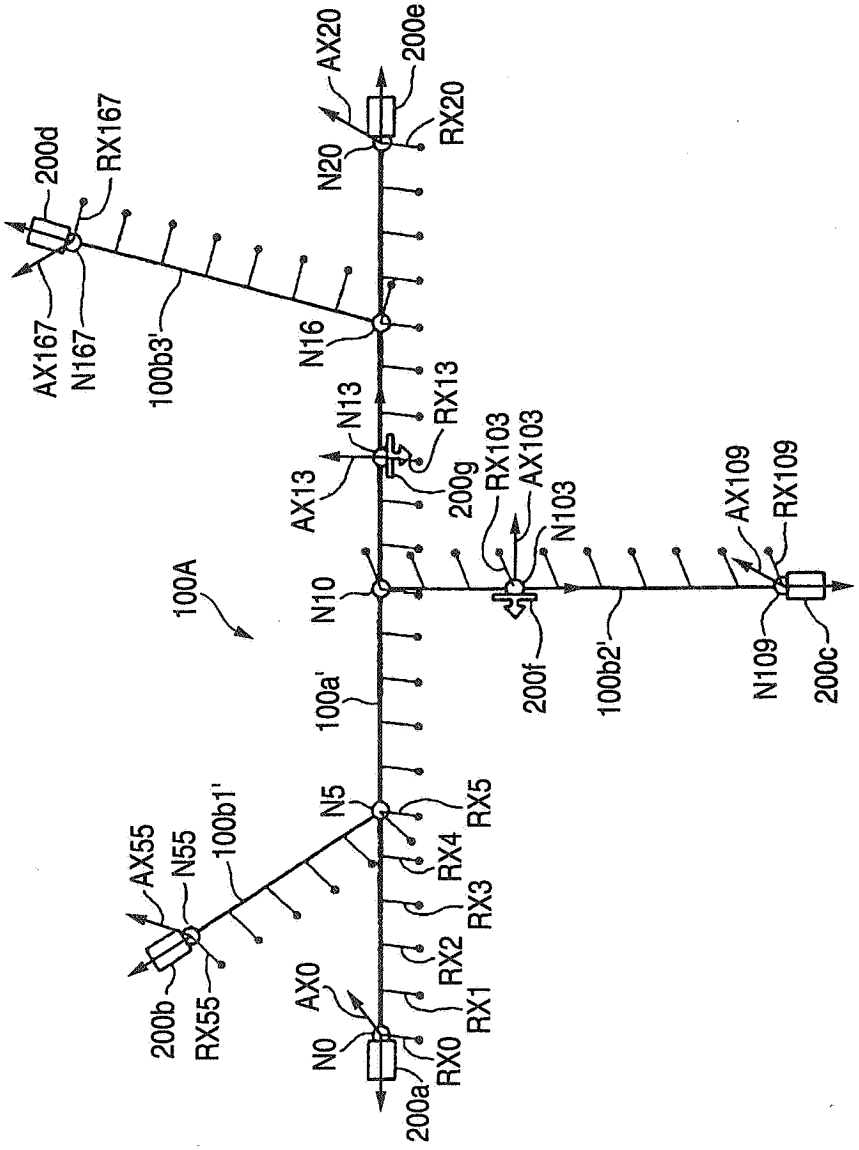

100A
100a'
100b1'
100b2'
100b3'
200a
200b
200c
200d
200e
200f
200g
AX0
AX13
AX20
AX55
AX103
AX109
AX167
N0
N5
N10
N16
N20
N55
N103
N109
N167
RX0
RX1
RX2
RX3
RX4
RX5
RX13
RX20
RX55
RX103
RX109
RX167

FIG. 19

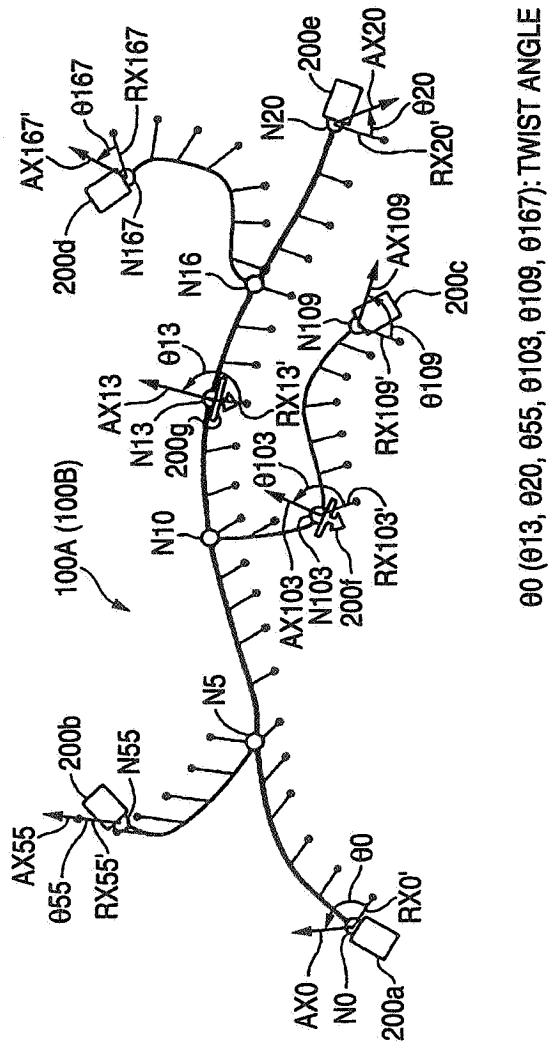

100A (100B)
200a
200b
200c
200d
200e
200f
200g
AX0
AX13
AX20
AX55
AX103
AX109
AX167
RX0'
RX13'
RX20'
RX55'
RX103'
RX109'
RX167
N0
N5
N10
N13
N16
N20
N55
N103
N109
N167
θ0
θ13
θ20
θ55
θ103
θ109
θ167
θ0 (θ13, θ20, θ55, θ103, θ109, θ167): TWIST ANGLE

FIG. 20

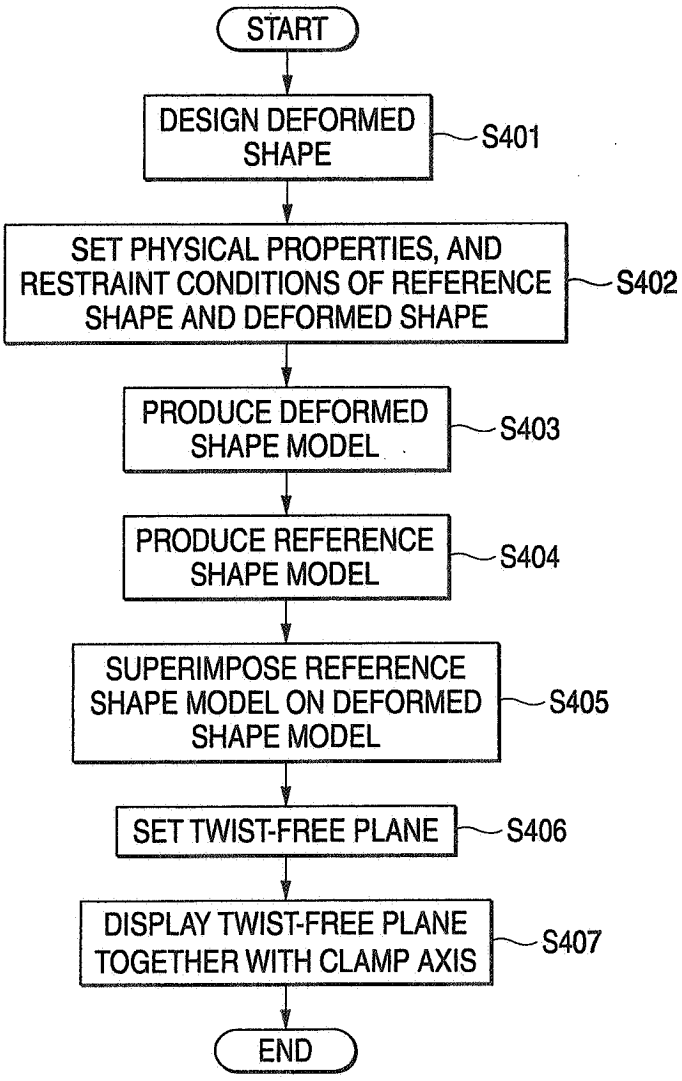

START
DESIGN DEFORMED SHAPE
S401
SET PHYSICAL PROPERTIES, AND RESTRAINT CONDITIONS OF REFERENCE SHAPE AND DEFORMED SHAPE
S402
PRODUCE DEFORMED SHAPE MODEL
S403
PRODUCE REFERENCE SHAPE MODEL
S404
SUPERIMPOSE REFERENCE SHAPE MODEL ON DEFORMED SHAPE MODEL
S405
SET TWIST-FREE PLANE
S406
DISPLAY TWIST-FREE PLANE TOGETHER WITH CLAMP AXIS
S407
END

FIG. 21

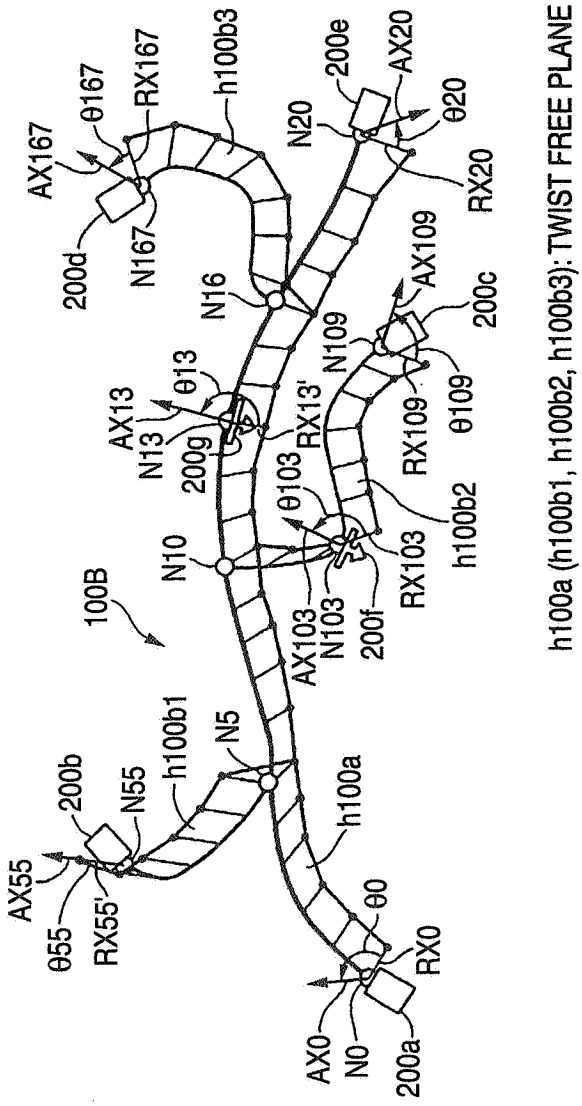

AX167
θ167
RX167
h100b3
200e
AX20
θ20
RX20
200d
N167
N16
N20
AX109
200c
N109
θ109
RX109
AX13
θ13
N13
200g
RX13'
θ103
RX103
h100b2
N10
100B
AX103
N103
200f
h100b1
N5
200b
N55
h100a
AX55
θ55
RX55'
θ0
RX0
AX0
N0
200a
h100a (h100b1, h100b2, h100b3): TWIST FREE PLANE

FIG. 22 (A)

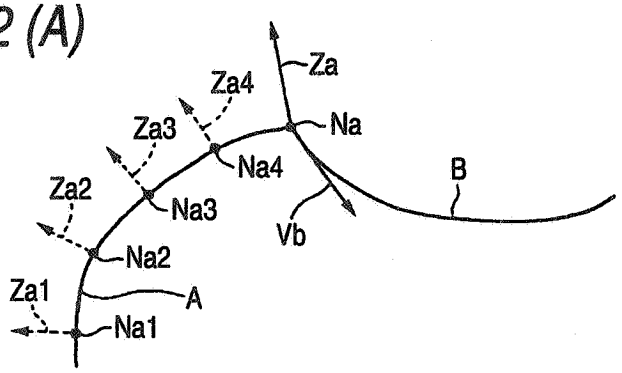


FIG. 22 (B)

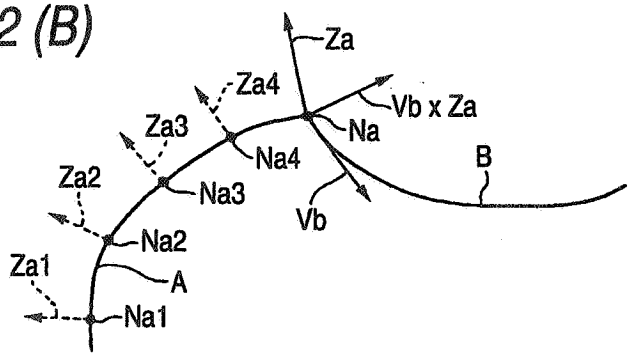
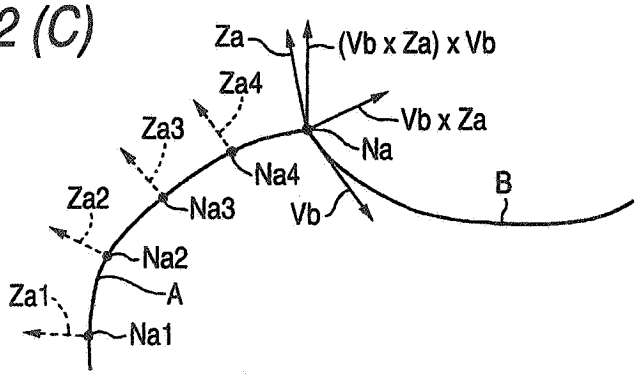



FIG. 22 (C)